DOCUMENT RESUME

ED 223 471 SE 039 726

AUTHOR Burtis, William S.
TITLE Ocean Opportunities. A Guide to What the Oceans Have to Offer.
INSTITUTION Institute of Electrical and Electronics Engineers, Inc., New York, N.Y.; Marine Technology Society, Washington, DC.
PUB DATE 82
NOTE 34p.
AVAILABLE FROM Marine Technology Society, Suite 412, 1730 "M" Street, NW, Washington, DC. ($2.00)
PUB TYPE Reference Materials - General (130) -- Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Careers; Environmental Education; Geology; High Schools; *Marine Biology; *Occupational Information; *Ocean Engineering; *Oceanography; *Science Careers; Science Education; Scientific Research; *Secondary School Science; Social Sciences

ABSTRACT

High school students interested in ocean-related careers will find their imagination piqued by "Ocean Opportunities." As the ocean's resources are recognized more and more as extremely important economically, yet very fragile, study of those resources is burgeoning. This multi-color booklet describes the exciting opportunities which ocean research provides; at the same time it clears up misconceptions about the nature of that work. Ocean careers and related information are presented in six chapters: (1) biological oceanography; (2) ocean engineering; (3) chemical oceanography; (4) geological oceanography; (5) physical oceanography; and (6) social sciences and the sea. Included in an appendix is an extensive listing of colleges, universities, schools, and other institutions and agencies that offer programs in ocean and marine studies. Some are career-training programs, some offer certificates, and most are degree-granting programs. (Author/JN)

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OCEAN Opportunities

A Guide
to what the oceans have to offer

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OCEAN Opportunities

A Guide
to what the oceans have to offer

from
The Institute of Electrical and Electronics Engineers
345 East 47th Street, New York, NY 10017
and
The Marine Technology Society
1730 M St., N.W., Washington, D.C. 20036

Funded through contributions from The Council of Oceanic Engineers, I.E.E.E.

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Production of this book was coordinated by The Marine Program
of the University of New Hampshire

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Design by
Ratta Associates

Color Photography by
David Mendelsohn ©

Dear Reader:

Everyone's life is touched by the oceans, if only by the weather patterns they produce. But most people are aware that the oceans are a means of transport, as well as a major source of food and, recently, mineral resources and fossil fuels.

For many people, the oceans are a place for fun and adventure. For some, they are a place to work. But for centuries, our knowledge of the oceans was very small, certainly in relation to the size and importance of the subject. You have probably heard before that the oceans cover about 72 percent of the earth's surface. But we know more, in some ways, about the surface of the moon than about the bottom of the sea; more about the structure of the atom than about the molecular complexities of the oceans.

Fortunately, this is changing. We rely on the oceans, sometimes testing to the breaking point their abilities to feed, cool, heat, cleanse, and carry us. Now we are beginning to ask not only what the sea can do for us, but what we are doing to the sea. It is clear that we must use the oceans wisely, or we will not have them to use at all. Our descendants, should that come to pass, would not remember us fondly.

Awareness of the fragile nature of the powerful but limited resources of the sea is growing around the world. Scientists and sailors, sociologists, economists, and lawyers—all kinds of people—are studying and discussing how we can make the most of the oceans' resources, while leaving them in the best condition for future generations.

The result, in addition to an expanding body of knowledge about the oceans, is a prodigious number of new technologies and specialties—in fact, a new outlook on the whole idea and nature of the oceans. A singular result is the clear need for further study.

The members of the Marine Technology Society and the Institute of Electrical and Electronics Engineers share the concern for the oceans. As leaders in research and the development of ocean studies and sciences, many of our members are finding the safest ways to use the oceans. In conjunction with this, one of our greatest concerns is educating people about the oceans.

We know that ocean careers are among the most exciting opportunities available; we also know that misconceptions about ocean careers are common, and we are eager to correct them. We want to see more good people taking an active, clearly understood, and committed part in what may be the greatest venture humankind has ever undertaken: making the oceans the best, most lasting resource we have. We hope this book will help make that happen.

Sincerely,

Dr. Donald M. Bolle
President
Council of Oceanographic Engineering
Institute of Electrical and
Electronics Engineers

Dr. Arthur E. Maxwell
President
Marine Technology Society

PREFACE

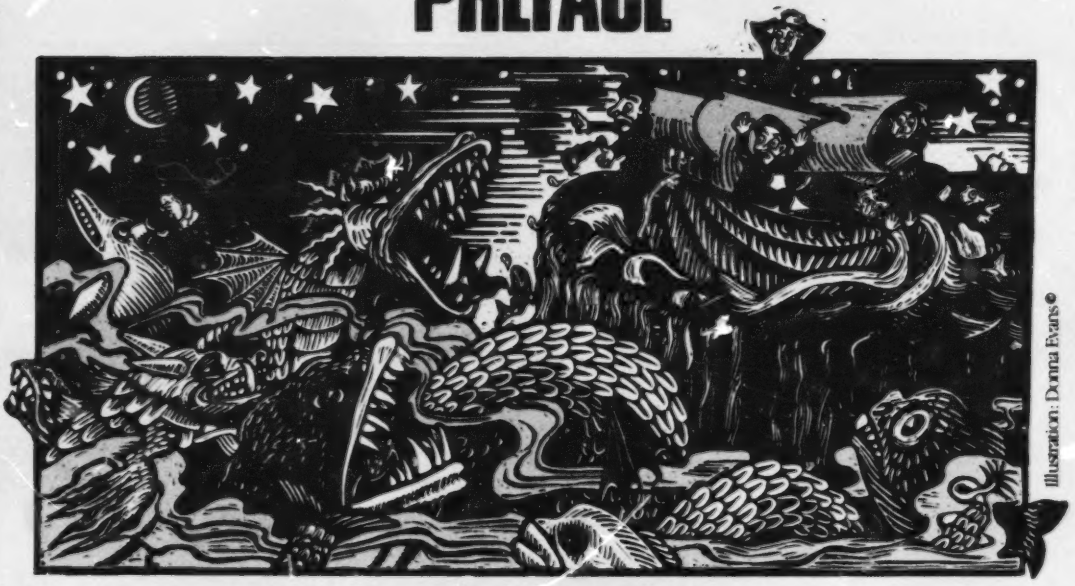


Illustration: Donna Evans©

The sea was once the ultimate border: the boundary line between existence and imagination; the place where what we knew ended and where what we could only guess at began. As much as the stars themselves, the oceans made us wonder: the edge of the water was the edge of the world.

Today, more is known about the stars and the oceans, but much more remains to be learned about both. A great deal of emphasis is now placed on ocean research and study, on mastering the power and potential of these vital, beautiful, dangerous, and exciting resources without damaging them. It is important, however, to put the nature of this adventure in perspective. The ocean is a place of romance and mystery: from Jonah and Jules Verne to Melville and de Maupassant, people know much of what they know about the oceans from stories, some of which are dramatically misleading.

Other stories provide accurate accounts of life and work at sea. Jacques Cousteau, aboard his research ship *Calypso*, has done much to make us aware of the oceans' grandeur, their beauty, intricacy, and delicacy. But Cousteau's odyssey is only a tiny part of ocean work today.

Beyond Cousteau

Contemporary ocean work includes the design of hydraulic and electrical systems to help us study the ocean; the investigation of the microcosm of ocean life; the examination of the effects of depths on divers; the construction of more efficient surface or subsurface craft; marine farming; and dozens of other important occupations.

As that short list implies, there are many things to do in and around the ocean. There are two reasons for that: first, ocean careers are usually land careers with an ocean application. A marine scientist, researcher, or engineer is a scientist, researcher, or engineer who has chosen to work on projects or subjects that involve the ocean.

Secondly, the ocean has become a hub for opportunities. When all we did was float on it and fish in it, the ocean offered a limited number of jobs. As we use the ocean for more complex tasks, we need to know more about how it works and what it is made of; as people from different fields apply their knowledge to the ocean, the numbers and kinds of "ocean professions" continue to grow.

In this "track" of *Ocean Opportunities: A Guide*, you will find listings of jobs in the professional areas on which the book focuses, chapter by chapter. Each listing will give a job title and a brief description of the kind of work the person does.

Unfortunately, because so many of these jobs are new and so many of the older jobs are wrapped in the often-inaccurate romantic garb of sail and slicker, there are a lot of misconceptions about ocean careers. One reason for this is that ocean careers tend to blur at the edges: biologists, chemists, engineers, physicists, geologists—people with many different skills work together on ocean projects. It is sometimes hard to see where the work of one leaves off and the work of another begins. But this interdisciplinary overlap is one of the wonderful things about ocean work, and one reason it is so exciting.

What you've got here

We can't accurately suggest—let alone describe—all the possibilities in ocean careers, so we're going to give you the elements you need to imagine them.

We're going to do this by talking about the work of five kinds of oceanographers: biologists, engineers, geologists, chemists, and physicists. Each of them has a chapter, in which we will describe a project typical of the kind of work these professionals do. We will, in essence, tell you stories about these people in order to give you an idea of their working lives: what they work on, where they work, and how they work.

One of the things you will find is that these "characters" tend to show up in each other's stories. You will also find a lot of other people there, too; some of them, like deck hands, won't be surprising; others, like computer operators, might be surprising.

In the sixth chapter, we will offer a broad perspective on the work of social scientists, lawyers, economists, and others as it relates to the oceans.

The book also includes a second "track," where we offer brief descriptions of jobs in the field in question, chapter by chapter. Chapters also talk about what kinds of preparation is needed for those jobs. An appendix offers a list of programs where you can get some of that preparation, as well as ideas on where to look for more information. Keep in mind that the careers we talk about here are *land* careers as well as ocean careers. If you want to know more about ocean engineering, for example, you could talk to any engineer about what engineers do.

The objective is to let you know as much as possible about what it means to work in an ocean career in order to give you a head start in planning. It used to be that a young person could spend a lot of time sampling the waters, so to speak. That's still true to some degree, but the realities of education and economics make too much sampling risky, particularly in technical fields. We live in a world of specialists, and it takes a lot of time, money, and effort to get the education to become one. So, it might be nice to have an idea of where you are headed before you start off.

Before you decide on any career, there are a lot of questions you have to ask. You have to look at yourself closely and try to identify what you like to do. What do you imagine yourself doing? What are your dreams? What kinds of things do you do for fun, and what do you find most rewarding?

Asking yourself a lot of questions is a good start, but let somebody else ask you

It would be impossible for us to list all the jobs relating to ocean work. We list here the jobs that serve as hubs of activity, and leave it to you to imagine the other people who might work with or for those people. For instance, if the work involves going to sea to collect samples, you can imagine it may require the services of a ship's captain and crew. Even though we don't list them, they are there.

As you will discover, most ocean careers are interwoven with many different kinds of jobs. As a result, we could list the job description for certain technicians, for example, in just about every chapter. We will do so, however, only if the technician is doing work specific to the work on which we focus in that chapter. In the case where a full description is not necessary because the information is contained in another chapter, you will find a listing like this:

Laboratory technicians:
(see chapter one)

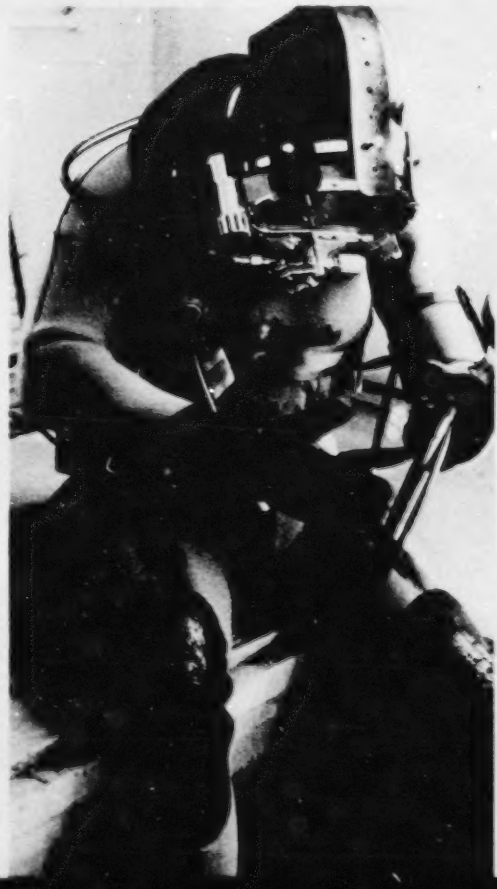
questions if you want to find out what your talents and preferences really are. Guidance counselors can be a good resource; they can also tell you about career preference tests that will help to identify where your abilities and interests lie.

A few cautions

- Just about all the scientific ocean careers involve a healthy grasp of and ability to use mathematics. That doesn't mean you have to like math, but it does mean you will have to know how to use it. Don't let that stop you, but keep it in mind.
- A career in ocean work takes dedication, discipline, and perseverance, as you would expect. Keep in mind that liking the ocean and liking working there are not the same thing: work is work, and ocean work can have its special problems, hardships, and hazards as well as its special rewards.
- No one can tell you what you'll like, and no one can tell you what you'll find in the job market. There will be jobs in ocean research and development, but it is safe to say that ocean careers ought to be considered for the love of them, not as a chance to get rich.

Career opportunities in ocean work will depend on employers' demands. More than 40 percent of the people in ocean careers work for the federal government, and that is also where the bulk of the money for ocean research has come from in the past. An equal number of ocean professionals work in academic settings, and the rest are employed in private industry. In some areas of ocean work, notably biology, there are already more people than there are jobs. On the other hand, there is currently a shortage of engineers and geologists; but that could change—it's hard to predict the market.

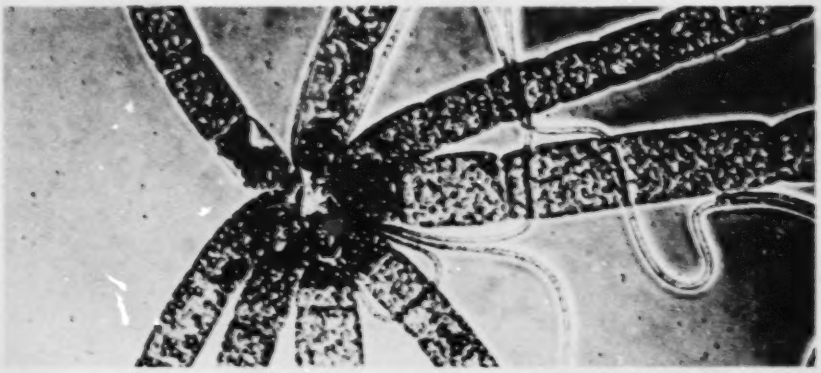
One thing is certain: there are jobs in marine fields, and there will continue to be jobs there. Ocean research and development will continue because it has to: we need the oceans' resources and we need the oceans as laboratories where we can continue to learn about our planet and ourselves.



Obviously, as the book goes along, you will find fewer and fewer full descriptions and more and more references to previous listings. But that is just another example of the interdisciplinary nature of marine careers—which becomes more and more evident as the book goes along!

CHAPTER 1
Biological Oceanography

or:
A man may fish with the worm that hath eat of a king, and eat of the fish that hath fed of that worm.
***Hamlet*, IV, iii**



Of all the ocean scientists, the biologist is probably the best known and the least understood. Ubiquitous collector of specimens, equally familiar in wetsuit, slicker, or lab coat, the biologist has long been regarded as *the* ocean scientist (which is probably why the market is currently swamped).

That is not surprising: aside from a means of transport, the ocean has been for centuries primarily a source of food. And the food, whether king crab, flounder, escargot, scallop, or seaweed, is alive; finding out how it gets and stays that way is what biologists do.

By biologist, we mean also botanist, zoologist, biochemist, ichthyologist, and microbiologist—anyone who studies the living things that, almost literally, pack

the oceans like a sardine can. Like the range of creatures and organisms in the ocean—from the single-celled to the blue whale—the variety and nature of the biologist's work is enormous.

One biologist might be sampling seawater for the presence of chlorophyll, which is indicative of plant life and plant functions—the beginning of the giant ocean food chain. Another may be studying the effect of depth and temperature on microscopic animal forms—the next link in that chain. Biologists study things like the spawning cycles of shellfish, the schooling patterns of blue fish, or the "speaking" patterns of dolphins or whales. Some even study *homo sapiens* in the ocean; in particular, the effects of depths and decompression on divers.

While biologists go to sea—and even into it—on occasion, their primary milieu is the laboratory, and their chief tool is observation—watching things to see how they live. The nature of biological research, experimentation, study, or recommendation may be theoretical or empirical. A biologist may be involved in postulating theories of the how and why of ocean life, or involved in the actual sampling, observing, dissecting, analyzing, testing—the proving or disproving of theories. Or both.

Most biological oceanographers live and work close to the ocean—if you need live samples, it's better not to live in Fargo or Butte. So, the decision for biologists to specialize in something like ichthyology (the study of fish) must have something to do with where they want to *be* as well as what they want to *do*.

If living near the ocean is a drawing card, another for the ocean biologist is a certain nobility in the enterprise. Most of these scientists—whether they are studying the mating habits of the grunion or the nervous system of the shrimp—are studying what lives in the ocean in order to keep it living: if we lose any link

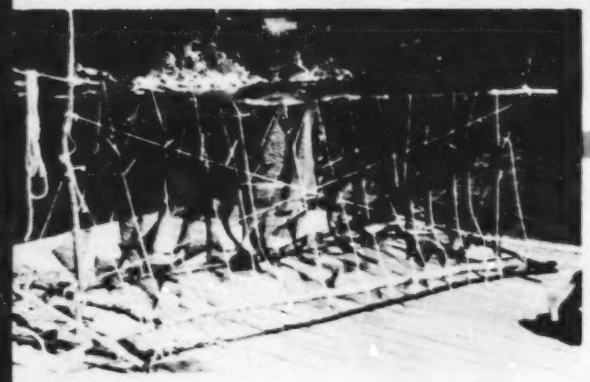
Biological oceanographer: studies marine animals and plants, their behavior and ecology, the natural balance between marine organisms; pollution and its effect on the marine ecosystem; the effect of marine organisms on man-made materials.

Fisheries biologist: surveys finfish and shellfish resources; monitors populations of various species; studies environmental factors, population dynamics, and fishing pressures; suggests management planning to conserve overfished populations; assists in keeping shellfish flats productive.

Aquaculturist: researchs, designs, and implements the commercial production of marine species and high-yield growth systems for marketing finfish, shellfish, shrimp and lobster.

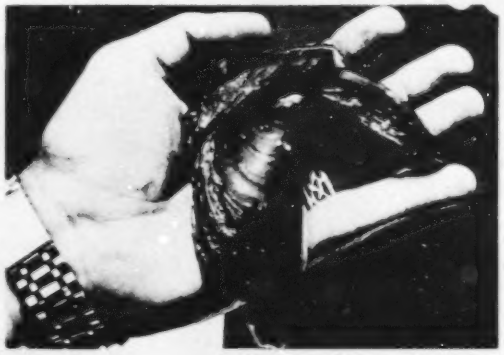
Marine microbiologist: identifies and investigates bacteria and their activities, including decomposition, their role in the food chain, as well as identifies diseases of marine life.

Planktologist: studies the distribution, abundance, population fluctuations, ecology, and taxonomy of planktonic organisms, plant or animal.



in the ocean food chain, we could lose the oceans—and the rest of the world wouldn't be far behind. The oceans feed themselves, clean themselves, and replenish themselves, but everything that lives there has a part in the process, and it is to our advantage to understand that well.

The ocean is, still, a primary source of food for the people of the world, and many people believe that, if correctly developed and managed, aquaculture—the science and business of ocean farming and husbandry—may someday "feed the world." Although that day is not around the corner, feeding the world is still not a bad business to be in—and it also provides an opportunity for our first ocean story.



One promising type of aquaculture is the commercial husbandry of blue mussels. It has promise because mussels are tasty, extraordinarily nutritious, and take pretty good care of themselves (which is why you see them just about everywhere along the shoreline).

The farming of mussels requires a number of things, chiefly including water of the right temperature and salinity, reasonable shelter from the ravages of ocean storms, lots of mussel food in the water, and a good annual spawn passing through the "farm." It also requires an elaborate system of rafts and ropes to which the mussels attach and on which they will live and grow fat.

It is the biologist who determines the best water temperature, what food the mussels like and need, how and when they spawn, what kind of surface they will grow on—things of that sort. A biologist does this by taking apart the biological life of the mussel. That means, first of all, having taken apart the mussel to understand its anatomy. What kind of nervous system does it have? How does it use the food it eats? How does it make its shell? How does it "breathe"—pump water in and out?

The biologist will also study the mollusk in its natural habitat, noting variables in diet, growth, lifespan, habits—the kinds of things biologists note when studying grizzly bears, chinchillas, or beef steers. They do this in all kinds of ways: weighing, measuring, inspecting; a lot of it is simply the gathering and analyzing of data—statistics that convert into theory, into more specific experimentation, and, finally, into advice for the mussel farmer (along with a request to be told about any strange behavior on the part of the farm animals).

To make calculations and judgments and carry out experiments and analyses, the biologist will make use of sophisticated equipment, from high-speed digital computers that analyze complex data, to electron microscopes that can make the fiberous structure of a cell visible—even photographable. There will also be work at the laboratory bench, examining tissue and shell, determining by chemical analysis what the creature was eating and "breathing." And not the least of the biologist's work is to keep up to date on the work of others in the field, reading professional journals and texts. The biologist, then, is a student, in this case studying the blue mussel.

The mussel farmer—who is a fisherman or woman, but who also might be a

Invertebrate zoologist: studies diverse areas such as: identification and classification of selected groups of invertebrates, their behavior, population, community structure and development, ecology, neurophysiology, and life histories.

Phycologist: studies algae taxonomy, physiology, or ecology, including distribution, abundance, reproduction, life-histories, and plant-animal relationships.

Physiologist: studies metabolic functions of plants and animal organs, tissues, and cells, and the effects of the marine environment on them.

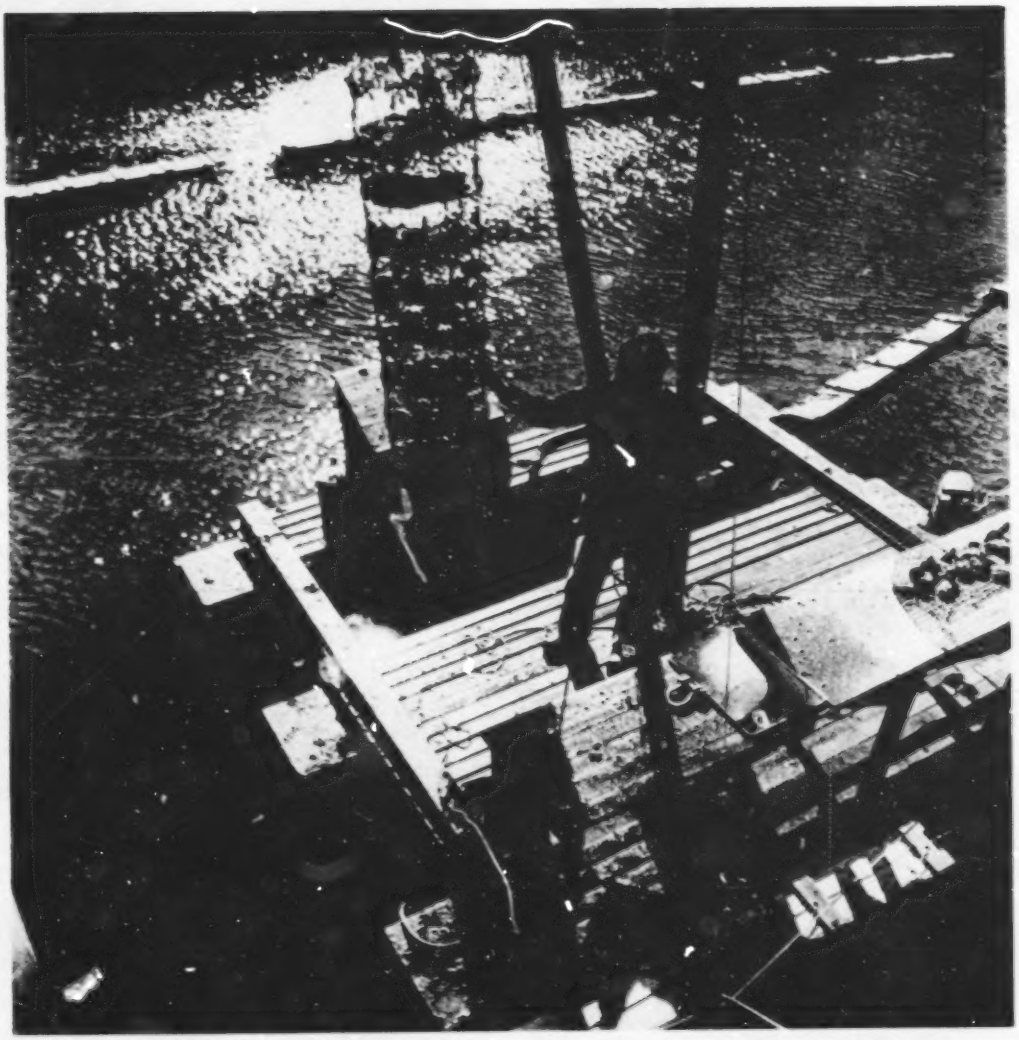
Biochemist: identifies and analyzes chemical processes related to the biological functions of marine plants and animals.

Marine mammalogist: studies marine mammals in aquariums and their natural habitat, their behavior, reproduction, diseases, populations, migrations, and abundance.

Biological technician: is responsible for a major portion of the data and specimen collecting of biological oceanographers; and conducts much of the experimental laboratory work under supervision of the scientists.

Fisheries technician: assists fisheries scientists with population and environmental surveys and techniques, including tagging procedures; collecting methods; organ and tissue removal; stomach content analyses. May also design and construct fishing gear and fishways, and aid in fish farming and hatchery.

Marine technician: (see chapter four)



biologist, chemist, or former welterweight champion, for that matter—is also going to seek the aid of the ocean engineer in creating the farm: designing the rafts and mooring systems to keep the rafts in place, and perhaps constructing a dock or a breakwater. The farmer will also ask physical oceanographers to help pick the right bottom and shoreline configurations for good water circulation. Chemical oceanographers will know what is in the water, and geological oceanographers can tell the farmer what will happen to the shape and size of the cove, river, or estuary where the crop is to be sown.

That's the way it is in ocean work—people bringing different skills and knowledge together to create solutions and new ideas. And that's the way it's always been, because the oceans are too big to handle alone.

Oceanographic technician: (see chapter three)

Oceanographic instrumentation technician: (see chapter five)

Applied research technician: (see chapter three)

Deck support technician: assists with all aspects of data and sample collecting on shipboard; rigs and operates instruments and sampling devices, repairs and stows much of the equipment; labels and organizes all equipment and samples for shipment to shore.

Scientific diver or underwater technician: studies and collects marine organisms in their natural habitat; handles research, navigational, and photographic equipment underwater to perform experimental techniques; may inspect, repair, remove, and install equipment and structures underwater; tests and operates underwater communications systems, photographic equipment, and closed circuit television.

Technical writer: (see chapter six)

Computer programmer: (see chapter two)

Computer operator: (see chapter five)

Systems programmer: (see chapter two)

Applied statistician: organizes, tabulates, and summarizes numerical data from scientific studies and sampling; performs statistical analyses and interprets data to emphasize significant differences and interrelationships between the factors studied; may make forecasts and predictions.

CHAPTER 2
Ocean Engineering

or:
When it's cold, awful, miserable, stormy, dark, deep, and lonely, who's going to walk the dog?

The work of engineers is everywhere, from the Washington Monument to the Golden Gate Bridge, from the space shuttle to the subway. Leonardo de Vinci was an engineer; so was Eiffel, so were Ford and Edison.

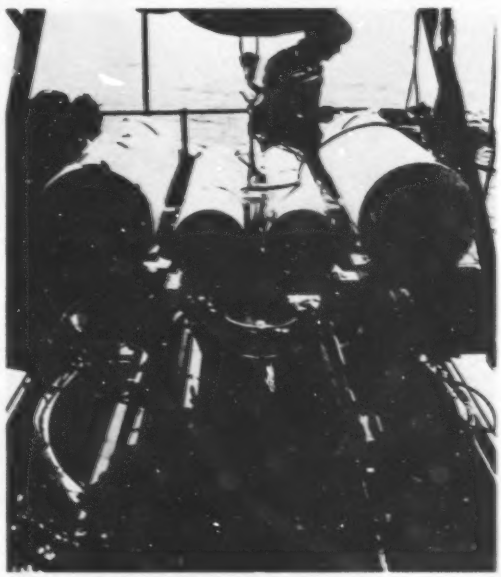
Engineers figure out how a thing has to be made in order to do what it's supposed to do. There are many different kinds of engineering, but the major designations in the field are chemical, civil, computer, electrical, and mechanical engineering. From the titles, you get some idea of the variety of work they do.

Like the biologist, the engineer's place of business is the laboratory—but it is a very different place from the biology lab. There may be heavy machines that can bend, twist, pummel, and squeeze steel, concrete, and other materials to test their strengths and resilience. There may be computers and calculators that help formulate and analyze mathematical models for aero- or hydrodynamic characteristics of vehicles and devices. There may be relatively simple gauges and instruments to measure electrical resistance or conductivity in computer circuits and hardware, or to measure tolerances in mechanical devices.

Sometimes the laboratory is outside, where tests of the load-bearing capacities of soils, pavements, and other materials are conducted, or where their resistance to earthquakes, salt, heat, cold, and other influences is measured. Or engineers may visit industrial sites to analyze the abilities of chemical compounds to lubricate, refrigerate, or incinerate, or to try out new mechanical "muscle" systems for automation.

Ocean engineers use their tools to answer the questions of other ocean specialists: they provide the *how* for the *why* or the *what* of the biologist or chemist, physicist or geologist. They are, therefore, in a pivotal position in ocean work, designing things without which research cannot proceed.

So, they design all kinds of things, from boats to breakwaters, ocean farms



to systems to keep dunes from eroding. One of the best-known feats of modern engineering is the "Texas tower," the floating platform that has made seabed oil drilling possible. The development of these floating communities, which are tough and stable enough to withstand ocean storms, but buoyant and mobile enough to be moved to other locations, is truly a remarkable accomplishment.

Like any other vehicle, structure, or community, the drilling platforms need maintenance, and preventative maintenance is critical in a hostile environment. Problems must be discovered before they become dangerous. Traditionally, inspecting such underwater structures—including boat hulls or bridge supports—has been the province of professional divers or, perhaps, a manned submersible.

Aside from the expense of such inspections, there are also concerns about safety and accuracy. Inspecting the

Ocean engineer: develops industrial materials and structures for working on or beneath the ocean surface, or along shore; expert in the design and construction of experimental oceanographic equipment.

Coastal engineer: studies the effects of currents, tides, and weather on the stability of coastal features, beach erosion, littoral drift; studies the physical forces that affect harbor, inlet, and waterway maintenance; provides valuable information for determining placement of dikes, pilings, drill rigs, and breakwaters, etc.

Oceanographic equipment engineer: designs and builds instruments and systems for oceanographic operations and research, and may work on the laying of cables, supervision of underwater construction, locating and recovering sunken ships, cargo, or equipment.

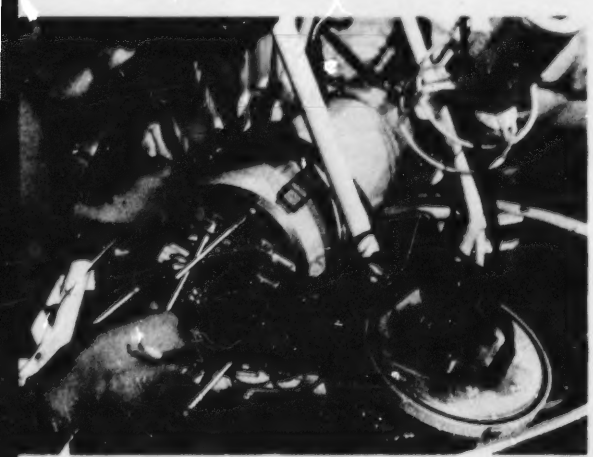
Electrical engineer: designs sophisticated electronic instrumentation to be used in all phases of oceanographic research.

Mechanical engineer: works on prototype design, development, and tooling of mechanical apparatus used for all aspects of oceanographic research and shipboard systems.

Civil engineer: plans, designs, supervises, and inspects construction and maintenance in shoreline, harbor, and other coastal areas; supervises field surveys and maintains data.

understructure of a drilling platform in the North Atlantic is not the easiest or safest occupation; inspecting pipelines and wellheads at the depths where they lie presents other special problems. It is the creation of a solution to these problems that provides our second ocean story.

The history of science is the record of scientific discoveries. One of the most influential advances of recent times is the "chip," a tiny bundle of circuits that has permitted the miniaturization of electrical devices. This advance in solid-state technology, made by electrical engineers, was capitalized upon by computer engineers, who perfected the microprocessor—the tiny computer.



The first application of this development to the problem of inspecting platforms and pipelines was the design, by electrical and acoustic engineers, of devices that use sound waves to inspect pipes, beams, welds, and structures for cracks and other signs of stress. Divers can take the devices underwater to scan whatever needs inspection. When the sound waves emitted bounce back to the scanner, their frequency tells a computer what is in the thing they've bounced off of—a crack, say, in a beam or a leak in a pipe. A computer picture can be produced, in which the faults will show up graphically.

But pipelines are long, oil-drilling platforms confusingly complex, and it would be nice if *people* didn't have to take the scanning devices down into the murk. So another team of engineers, including electrical and computer experts, but also mechanical engineers, set out to design a vehicle that could follow a pipeline or cable, swim up into the structure of an oil platform and, using the same acoustical testing apparatus as well as video equipment, make the necessary inspections. It would be a robot.

The task required many different skills and talents. To begin, mechanical engineers used their knowledge of materials to decide what to make the vehicle out of and how to hold it together. After the electrical and computer engineers had figured out how to program the robot's brain and give it power and a nervous system (all protected from the prying, corrosive fingers of ocean salt and water, not to mention . . . sharks?), the mechanical engineers had to figure out what kind of muscles to give the robot and how to make them work.

From a question seemingly as simple as whether to weld or lug a joint—or will we use fiberglass?—to something as complex as designing hydraulic systems to allow the robot to swim, steer, find its way around, and perform its function, it took a lot of testing, measuring, calculating, and trying again. Working in offices and laboratories, armed with testing equipment and computers, rulers, pocket calculators, and scratch pads, the engineers proposed designs, created computer models and simulations, actual models for small-scale tests, and gradually refined their design.

Finally, after the blueprints were drawn, after the machinists and welders and electricians and other ocean craftspeople had put the whole thing together, the engineers took their creation out for a trial run, to see if it would swim . . . and think and act. They put it on a boat and took it out to sea, gave it a task to do,

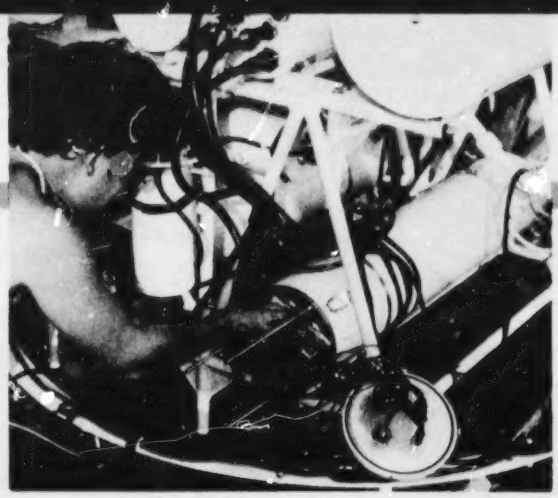
Acoustical engineer: is responsible for the design and implementation of sound systems used in the marine environment for remote sensing (sonar), underwater communications, location of gas and oil reserves, etc.

Fisheries engineer: designs and operates a wide range of gear used in fishing, and fisheries management and research.

Marine engineering technician: works with hydromechanics, waterfront structures, and amphibious equipment to aid in research and development for coastal and marine engineering projects; assists research engineers with experiments, theoretical investigations, machine computations, etc.

Computer programmer: is responsible for data entry and computer software applications to compile, integrate, and analyze scientific information gathered.

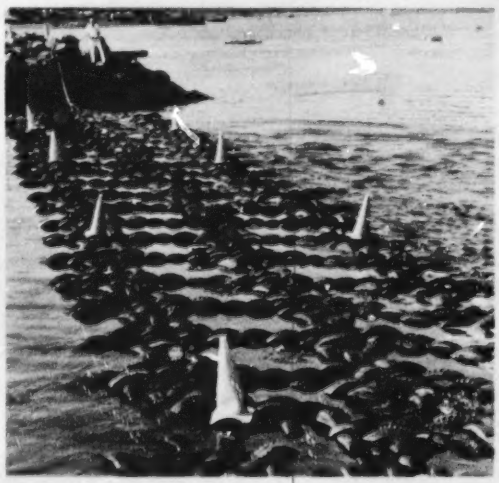
Systems programmer: is responsible for the proper functioning on computer hardware and software, keeps track of the system and provides general system support.



dumped it in the water . . . and it worked.

It took months of exacting, painstaking analysis and rethinking, but they had created a robot that was light but strong, capable of carrying its own power, computer and memory, sensing equipment, and propulsion units, but was still seaworthy and maneuverable. Best of all, it would allow other ocean workers to do their jobs better and more safely.

It may be that other ocean scientists will be able to make use of robots like the ones now "in training" for inspection duties. Biologists, for example, might use them to collect samples during ocean storms, when the agitated water carries more information. Likewise, chemical, physical, and geological oceanographers may find robots useful in their work, which we will look at in succeeding chapters.



Like most technological advances, new applications will be discovered. That process goes on everywhere. Unlike biologists, ocean engineers, for the most part, have no special need to live close to the ocean. In some cases, being close to water is helpful for testing, but most of the engineer's work can be done in the laboratory. Because ocean engineers are usually working on something that will *go into* the water, not something that has *come from* the water, they can work almost anywhere.

For some, like civil engineers who design systems to prevent shoreline erosion, salt marsh degradation, or look for ways of constructing things that will not harm delicate coastal environments, it is a good idea to work near those environments. And for engineers involved in naval architecture, proximity to shipyards makes sense.

Wherever it exists, the expertise of engineers is central to the work of many people in ocean careers. Besides the scientists who count on engineers to show them ways of getting the information they need, there are numerous businesses and industries that use or make the things engineers design, whether that is a safer oil platform, a better ship's hull, a steadier harbor buoy, a sounder breakwater—or a submersible robot. And it's not far-fetched to say that the people who work for those businesses are ocean welders, ocean drafters, ocean computer operators, even ocean accountants. From sea captain to secretary, the ocean touches many professions.

Marine technician: (see chapter four)

Applied research technician: (see chapter three)

Deck support technician: (see chapter one)

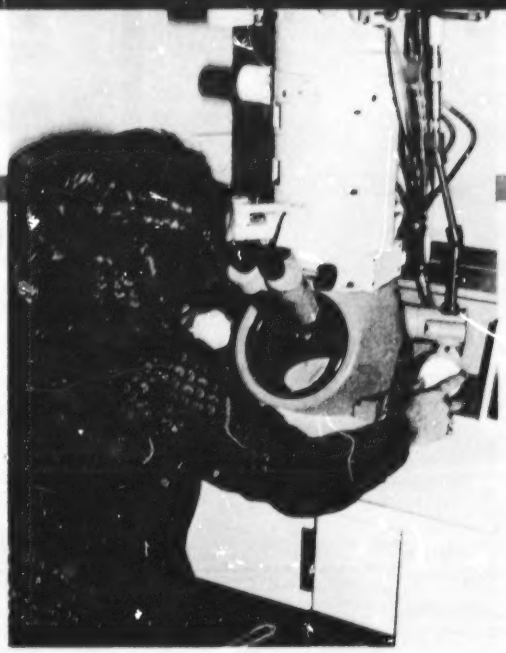
Scientific diver or underwater technician: (see chapter one)

Technical writer: (see chapter six)

Computer operator: (see chapter five)

CHAPTER 3
Chemical Oceanography

or:
This tastes good. What's in it?



We, like everything within the earth's atmosphere, are chemical. We breathe chemical elements, eat them, wear them, and walk on them. Lately, we have become increasingly concerned about what kinds of chemicals we breathe, eat, and wear, and that has tended to give the term "chemical" a bad name.

But the purest water is still hydrogen and oxygen, and sodium chloride is what makes the oceans salty. There are thousands of chemicals and chemical compounds in the oceans, and finding out what they are and how they work in the systems of the seas is the job of the chemical oceanographer.

Because chemical elements are microscopic and everywhere, the work of any chemist is complex, exacting, and delicate. Discovering what elements are present in the ocean—or anywhere else—requires highly sophisticated instruments and careful analysis. Typically, instruments that provide such data are very expensive and must be operated by trained technicians. Some use electrical currents or magnetic fields to identify different elements and measure how much of each element is in a sample. An electron microscope, for example, bombards a sample with electrons in order to "see" it at thousands of times its actual size.

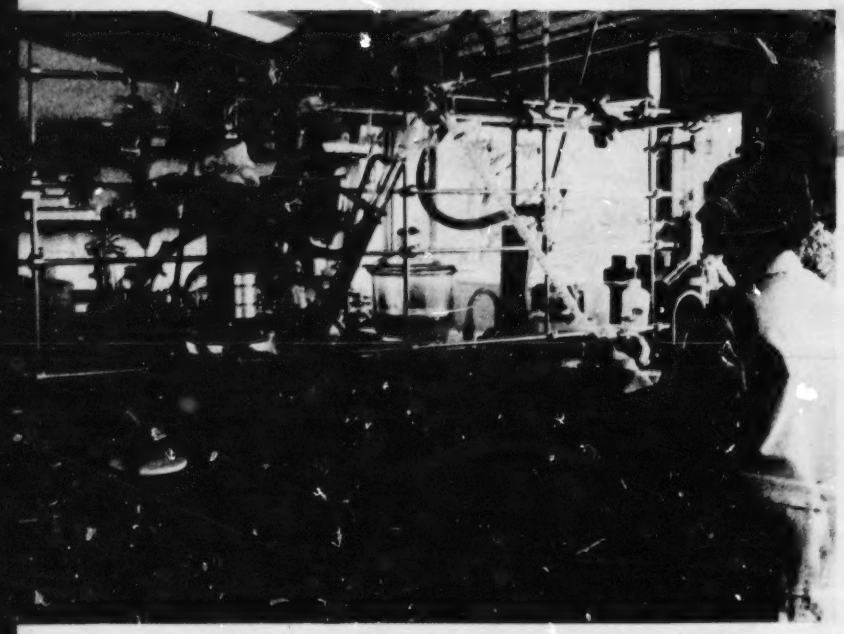
In order to get their samples, ocean chemists have to go to the ocean. Because samples are altered by time, temperature, transport, and other factors, ocean chemists, like ocean biologists, usually work very near the ocean, often in laboratories located on the coast. Sometimes, analyses must be performed immediately, right on the water. For every day (and *some* of them will be rainy and stormy) spent taking samples, there will be several days in the lab, working with chemicals, heating reagents, measuring, waiting, observing, noting.

After the analyses are made and the data gathered, the chemist's job is far from done. It is then that the special knowledge of how elements act and interact comes in—the chemistry of chemistry. It is not enough to know what's there; you have to be able to tell why it's there and what it's likely to do—what it may be good for or what it may be bad for.

So the work of the chemist begins in the field, taking samples, and proceeds to the laboratory—to instruments and beakers and computers—and ends in the mental process of applying the knowledge of chemistry to the data gathered and turning the conclusions into solutions for society's problems. It is very precise work and, perhaps more important, it is often very subtle work.

A great deal of the ocean chemist's work takes place not on what we call the "high seas," but in bays, estuaries, and near-shore waters—where the greatest concentrations of nutrients necessary for marine life tend to be and where much of ocean life originates. In our first ocean story, about biologists and the husbandry of blue mussels, we noted that the mussel farmer might call upon a chemical oceanographer to measure the "farm's" suitability for growing mussels. The ocean chemist conducting such a study might also be a sedimentologist, because what he or she examines is sediments

Chemical oceanographer: studies the chemical composition of seawater and of ocean sediments, the relationships between organic and inorganic compounds, and the presence, sources, and roles of dissolved nutrients and organic matter in the ocean; conducts research on desalinization, extraction potentials of rare, valuable seawater components, and is the primary specialist in the area of ocean pollution.



bacteria eat away at organic wastes, returning them into the ecosystem as useful elements. The same idea is behind the use of mulching toilets, sewage-sludge treatment plants, and cow manure on the vegetable garden.

in the water—how much of it is good food and how much of it is, well, junk food. In this third ocean story, ocean chemists are trying to discover if some of that sediment might be just plain poison.

We hear a good deal today about environmental impact studies, in which chemists and other scientists project the effect a given human activity might have on nature. Unfortunately, human activities were going on long before anyone realized that some of them might be having an adverse effect on anything. Some scientists are trying to find out how much continuing effect those old transgressions might be having now.

In this instance, chemists are studying the chemical processes in an estuary to see the effect they are having on certain "heavy" or toxic metals present in the sediment on the bottom. One such metal, chromium, is there because a river emptying into the estuary was used to carry away wastes from a mill that used chromium in the tanning of leather.

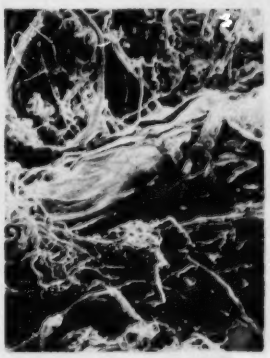
Until the 1960s, such dumping was legal, because not many people realized the metals were not carried away, but deposited where they might do harm to fish and other marine life. The problem today is that, although the chromium is assumed to be safely buried in sediments, some amounts of it may be "reactivated" by processes of chemical degradation. The irony is that those same processes also keep the planet clean:

In this case, however, those bacteria, as they do their work degrading organic material in the bottom sediment of the estuary, may also be releasing inorganic chromium into the water, where it might become part of the meat of fish, clams, and other things that might end up in our stomachs.

Large amounts of chromium are not good for fish or humans. In fact, if it is oxidized in a certain way, it is very toxic, even lethal. The chemical oceanographers working in this project are trying, therefore, to find out a number of things. First, how much chromium is present; second, is it being released into the water; and third, is it being released in a toxic form and in sufficient quantities to do harm?

The first step in finding the answer is sampling. From small craft, perhaps no larger than a rowboat, the ocean chemists use a device called a box core to take samples of the sediment on the bottom. These core samples are something like what you get if you stick a straw into the dirt and pull it out again, and they show not only what is in the sediment, but how close to the surface it is.

A complication to this sampling process is that the work of bacteria in this environment is anaerobic—without air. If air gets into the sample, the bacteria die, and the chemists will have no chance to measure the actual degradation process. They will still have a sample of what's there, but not what it's doing or how fast. So the whole sample has to be



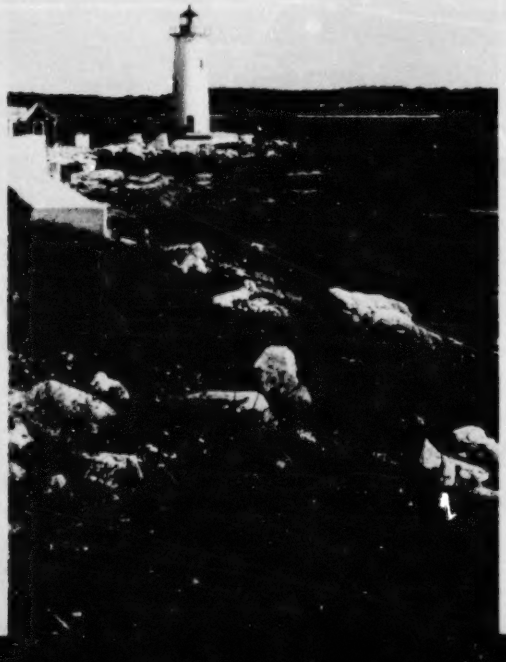
Chemical technician: assists chemical oceanographers by assembling and using scientific chemical apparatus, conducting analytical laboratory measurements, and tabulates and analyzes data.

Water pollution technician: measures the levels of pollution in oceans, bays, and estuaries; conducts research on various control and abatement procedures for all types of pollution; helps survey geographic areas being studied; designs sampling techniques; and studies the ecology of polluted areas.

kept anaerobic, right into the laboratory experiments and analyses. Obviously, if the laboratory is in Butte or Fargo, the complicated becomes the ridiculous.

Once in the laboratory, the anaerobic sample is analyzed. The sediment is measured and identified, with particular attention given to the presence of chromium. The core is tested for the amount and rate of bacterial activity, and how that is affecting organic and inorganic bonding. From that, the chemists can measure how much chromium might be released and in what form.

The actual sampling and preparation of the samples for analysis may take an entire day—and that's for one sample from one spot in the estuary. The actual analysis may take several days, depending on the size of the sample and the subtlety of the bacterial action. When all the data is gathered, the final process of examining the information and drawing conclusions from it may take longer than all the work that went before. From field work to laboratory work to desk work, it is challenging, painstaking, exacting, and exciting—good work for a good cause.



Like most ocean workers, the chemical oceanographer does not work alone, but with the aid of biologists, geologists, and physicists, who will know the effects of chemicals on life forms, the characteristics of sediments, and how currents move them around. Chances are, too, that it was an engineer who designed and constructed the coring device the chemists use for sampling. In crucial support positions are technicians, instrument operators, and many others, making their contributions in ocean work. Together, they help make the oceans less foreign and less vulnerable, and teach us how to use a valuable chemical resource.

Applied research technician: uses oceanographic knowledge to design new equipment to be used for specific or unique problems or tasks.

Oceanographic technician: assists oceanographers with testing and analysis; maintains and equips the laboratory on shore and on shipboard; calibrates and operates research instruments; is responsible for record-keeping, data reduction, and graphics of the results.

Marine technician: (see chapter four)

Oceanographic instrumentation technician: (see chapter five)

Deck support technician: (see chapter one)

Scientific diver or underwater technician: (see chapter one)

Technical writer: (see chapter six)

Computer programmer: (see chapter two)

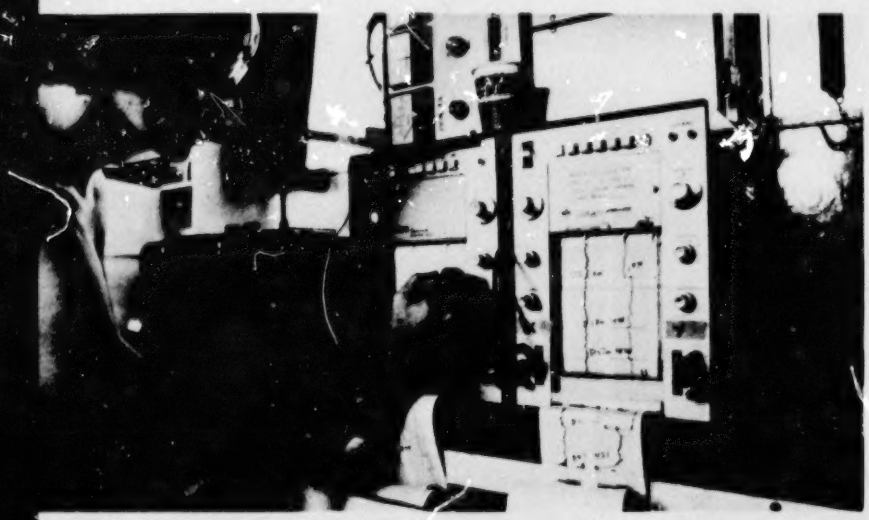
Systems programmer: (see chapter two)

Applied statistician: (see chapter one)

CHAPTER 4
Geological Oceanography

or:

It was all in the finding I thought. Once you found it, you just picked it up and put it into sacks and carried it to the nearest bank.
—Humphrey Bogart as Fred C. Dobbs;
The Treasure of the Sierra Madre.



Looking at most relief maps of the earth, you are struck by the swirling complexities of the Himalayas, the great spine of the Andes and the Rockies, or the lacy veinwork of the Amazon basin, stretching like lightning across the shoulders of South America.

The oceans are usually blue blanks, great panes of space. On the surface, that's just about what they are. We know, of course, that this is not true on the bottom. There are mountains under the sea to compete with the grandest Tibet can offer, and trenches to make the Grand Canyon seem the work of a penknife. There are plains, valleys, and rivers.

It took centuries to map the surface of the land, and we are still correcting even our latest efforts. While we know, thanks to satellites, what we look like, we still have a lot to learn about what we are made of and how the earth functions as a mineral mass. Such discoveries are the fundamental task of the geologist: finding out what minerals compose the earth and how they came to be there—which helps us to know how the earth came to be here.

Since almost three quarters of the earth is under the oceans, marine geologists have a particularly big job. That job is severely complicated by the fact that we can't even see the ocean floor, much less study it. Becoming familiar with the bottom of the sea is an enormous challenge.

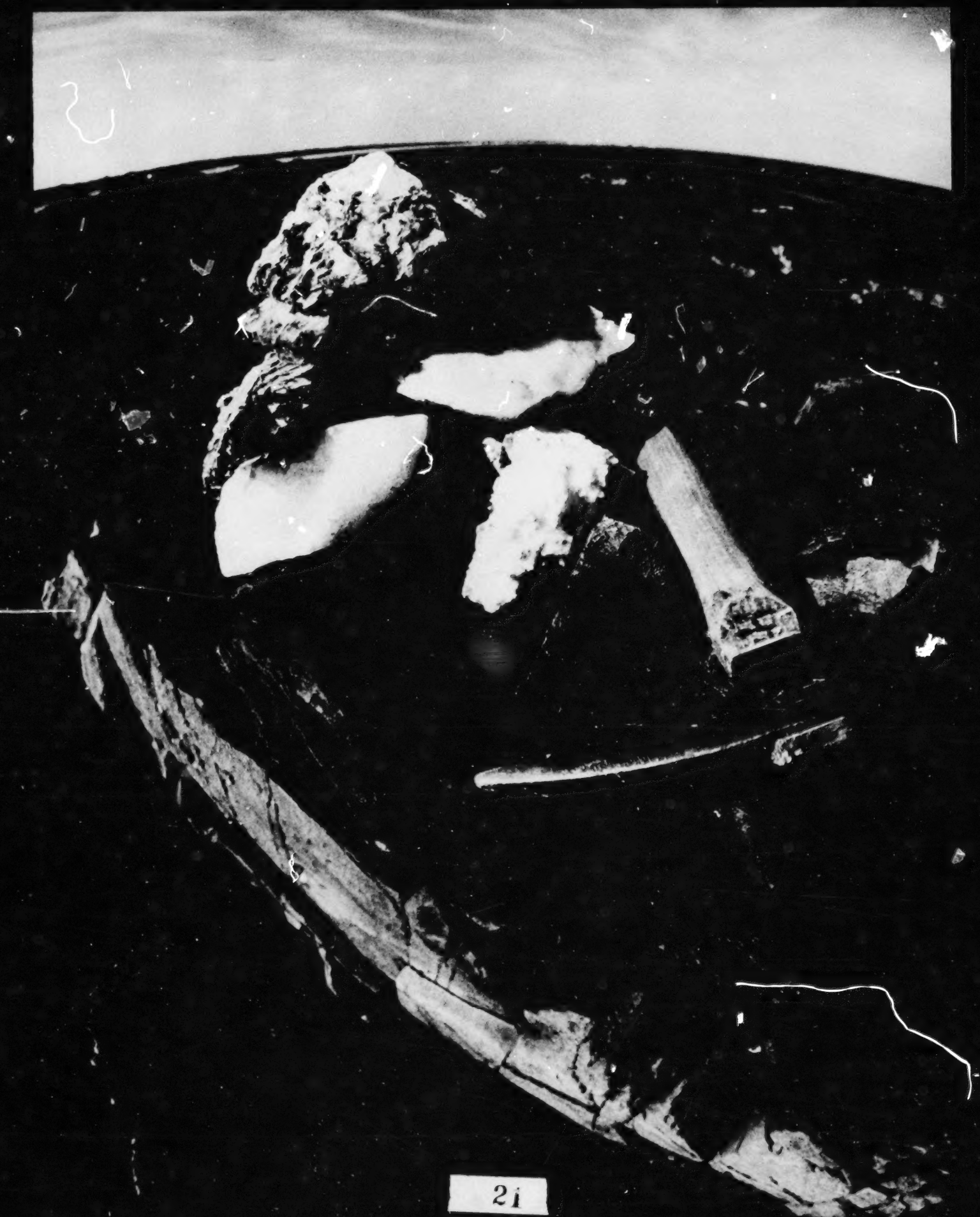
Ocean geology is one of the latest of the marine sciences, largely because we didn't care much about the ocean bottom for a long time. We wanted to know where it was, roughly, so it didn't punch holes in the bottoms of our boats, but beyond that, well . . . it was just down there. Somewhere.

But we began to use it, gradually. We sunk moorings into it, laid pipelines and cables on it. Later, we built things on it, and now we are starting to mine it. We also understand now that the shape and variability of the ocean floor can affect our lives by altering or creating ocean currents.

In the early 1900s, Alfred Wegener, a German meteorologist, posited the theory of continental drift—that the earth's crust is made of huge chunks of rock, floating on a molten sea of their own. Although he was scorned for decades, scientists now agree with his theory, and that has spawned ocean geological studies, because the deep-ocean trenches and ridges are where most evidence of tec-

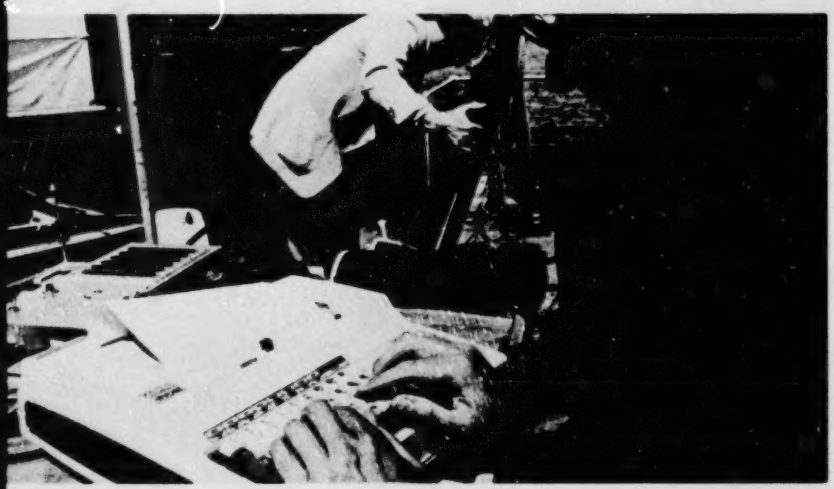
Geological oceanographer: examines fossils, rocks, minerals, and sediments to determine changes which reveal processes occurring in the earth's history; studies ocean floor topographic features and rock and sediment characteristics and distributions; assists in the discovery of petroleum, natural gas, and mineral resources; may assist in the engineering of structures connected with the ocean floor; might work on the problem of increasing our supplies of heavy metals by probing environmental information on mineral resource deposits on the continental shelf.

Geological technician: assists geological oceanographers in analyses of the components of the earth's crust beneath the ocean, in preparing maps and charts of the topography of the ocean floor, and in analyzing research data on sediment characteristics to determine sediment transport.



tonic activity can be found. In fact, the ocean bottoms are the most active places, geologically speaking, on earth. Knowing what that activity is and what causes it is important to our knowledge of the planet. It's also important to monitor that activity because it can cause earthquakes and volcanos.

Despite our new interest in what's down there, most of our maps of the ocean floor are still only approximations of reality—good for navigation and fishing, perhaps, but not specific enough for some of the newer ocean technologies.



For instance, even if we know the shape of the bottom, we may not know whether that is the shape of sediment or bedrock. That difference is important to people who want to lay oil pipelines or conduct mining operations. The miners also want to know what minerals are in the bedrock: iron, manganese, tin, copper, nickel; even silver, gold, or diamonds.

To find out what really lies under the oceans, geologists become the Lewises and Clarks of the seabed. In the process of finding out what the ocean bottoms are made of, they are also cartographers, creating maps of the ocean floor as a kind of by-product of their explorations.

One such expedition, and the subject of this ocean story, is on the inner part of the continental shelf off the east coast of the United States. A group of geologists, working with the U.S. Geological Survey, is charting and sampling the seabottom there—steaming back and forth over it, taking measurements with a variety of sonar scanners and magnetic-field surveying equipment.

Some ocean geologists, working on deep-ocean projects, may join other scientists on large research ships and go to sea for months, surveying vast amounts of ocean acreage. But this continental shelf study is close enough to shore to allow the scientists to go out one day at a time. Although it is nice for them to go home from work at night, they go home late.

Some of the instruments these scientists are using work by sending signals to the bottom and recording their response. The simplest of the devices creates a seismic profile of the bottom by bouncing sound waves off it and recording the echoes from sediment and bedrock. The resulting cross-section shows the depth of the water to sediment or bedrock, or the depth of sediment to bedrock, directly below the ship. The most complex of the instruments measures the magnetic field along the ocean surface. Changes in the field identify different kinds of seafloor bedrock by the intensity of the change.

Tying those instruments together to give a "picture" of the ocean bottom is a device called a side-scan sonar. By sending sound waves out to the sides of the boat at an angle, the side-scan is able to produce a three-dimensional representation of the bottom. Because it shows

Cartographer: compiles data pertaining to the physical features of the ocean floor; designs and constructs maps.

Hydrographic survey technician: operates surveying, measuring, and navigational instruments such as sextants, depth recorders, bottom grabs, and wire drags; reads charts and assists cartographers in the field with data acquisition; processes, analyzes, and interprets the data.

Geographer: studies special characteristics of the earth's terrain, sediments, magnetic field, vegetation, and climate in relationship to the oceans; may do surveying, meteorological data collecting; construction and analysis of maps, graphs and diagrams; interprets aerial photographs, and observational field data.

Marine technician: specializes in electronics; is responsible for handling, calibrating, and maintaining shipboard and laboratory scientific equipment; assists scientists and engineers; may work with submersible recorders and remote sensors to collect and store data from measurements made at sea.

cracks, joints, and other characteristics of the bedrock and sediment, the side-scan also helps to verify the magnetic and seismic impression of what kind of rock, sand, or silt is on the bottom.

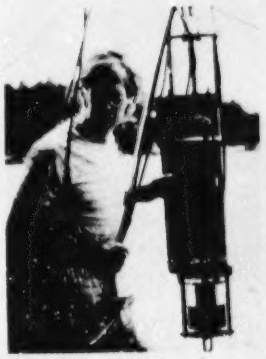
As the boat passes over the ocean bottom, all three instruments record simultaneously, mapping a swath about 400 meters wide. (In deep-ocean projects, scientists may use side-scanners with a range of from 30 to 50 miles.) During such data-gathering cruises, the work of the geologist is primarily keeping track of the performance of the instruments. It may sound simple, but keeping things running, and checking the data to make sure things are running *right*, makes it a busy day.

Once they have completed a day's cruise, accumulating computer printouts and graphs or plots and digital readings from the instruments, the scientists must return to the laboratory and the computer, where they will merge the information from three sources into one clear picture of the seafloor.

By correlating the information, they can see, for instance, that a bump on the seismic profile is actually a ridge, as shown by the side-scan, while the magnetic-field survey indicates that the ridge is made of granite. Just beyond the ridge, the profile shows a drop, the bedrock buried under many feet of sediment, . . . and so on. Piece by piece, the geologists create a series of maps that show what the bottom looks like and indicate what it is made of.

The final task for these geologists is to apply their special knowledge of how rock is formed and moved and shaped, interpreting the maps to say why what is there is there. Was it formed by pre-glacial volcanic activity? Is it glacial residue? If it is post-glacial, how did it get there? By answering such questions, the ocean geologists expand upon the information of the maps, since glacial and pre- and post-glacial formations are themselves clues to the nature of what is around them. The new knowledge the geological oceanographer presents also helps answer larger questions about how the earth was formed and about the evolution of life forms. What they learn about how ocean sediments move around is important to drillers and miners and harbor masters.

Whether they are on a day cruise over shallow waters or out for months over the deep sea, ocean geologists are collecting important pieces of a fascinating puzzle. They are creating a picture of a hidden landscape—a picture other scientists will use in their work, and one which is an essential part of the emerging portrait of the oceans that all the ocean workers are painting.



Oceanographic technician: (see chapter three)

Oceanographic instrumentation technician: (see chapter five)

Applied research technician: (see chapter three)

Deck support technician: (see chapter one)

Scientific diver or underwater technician: (see chapter one)

Technical writer: (see chapter six)

Computer programmer: (see chapter two)

Computer operator: (see chapter five)

Systems programmer: (see chapter two)

Applied statistician: (see chapter one)

CHAPTER 5
Physical Oceanography

or:
Does E still equal MC²
20,000 leagues under the sea?

We've all heard stories about the power of the ocean. Ocean waves—from the mythical proportions of the dread tsunami or tidal wave to the gentle but persistent lapping of a calm sea—are the most common example.

Tides and currents are other expressions of the power of the oceans. Studying that power, finding out where it comes from and what it does, is the province of the physical oceanographer.

Physical oceanographer: studies the physical properties of the ocean such as temperature, density, wind and wave action, tides, circulation patterns, underwater light and sound transmission, interrelationships between the ocean and the atmosphere, and harnessing the ocean's power for energy; may make predictions about the tides, weather patterns, iceberg movements, fish movements, etc.

The term physical oceanographer is an apt one, for these men and women are most directly concerned with the oceans as mass in motion—the physics of the oceans. Unlike other ocean scientists, who examine what is in, under, or around the water, ocean physicists study the water itself—how it moves and where it moves. Like other oceanographers, they use biology, chemistry, engineering, geology, and other sciences to help them in their work.

It is important to study the oceans as physical entities because of their power. They can and do erode shorelines, fill in channels and create new ones, and present hazards and opportunities with their currents and tides.

There are also more subtle, less easily understood things that happen because of the behavior of the oceans. Cold ocean currents move north and south from polar oceans, bringing cool air with them, and run into warmer waters and currents and the air above them, creating weather patterns—including hurricanes and typhoons. The movement of the currents is also the movement of what is in or on the water: the plankton that fish eat or that make shellfish meaty; a disabled ship or a life-raft, which will be a much easier needle to find in the haystack of the ocean if you know where it will drift.

Although satellites can now provide us with a lot of data, to find out what makes the oceans move and how they move, physical oceanographers still have to go to sea. They monitor the water in the deep sea, far from land, and in the shallow waters of estuaries, bays, coves, river deltas, and inlets close to shore. Using a variety of instruments and techniques, the ocean physicist records and analyzes different characteristics of the water, such as depth, pressure, temperature, salinity, density, direction, and velocity. Recording wind speeds, air temperatures, moon phases, sunlight, darkness, and other variables is also part of the job, to find out how such phenomena contribute to ocean action and to discover how the oceans affect things in return.

Like other ocean scientists, physical oceanographers spend a good part of their time in laboratories and at desks, analyzing data. While those desks and labs may be far from the ocean, they are

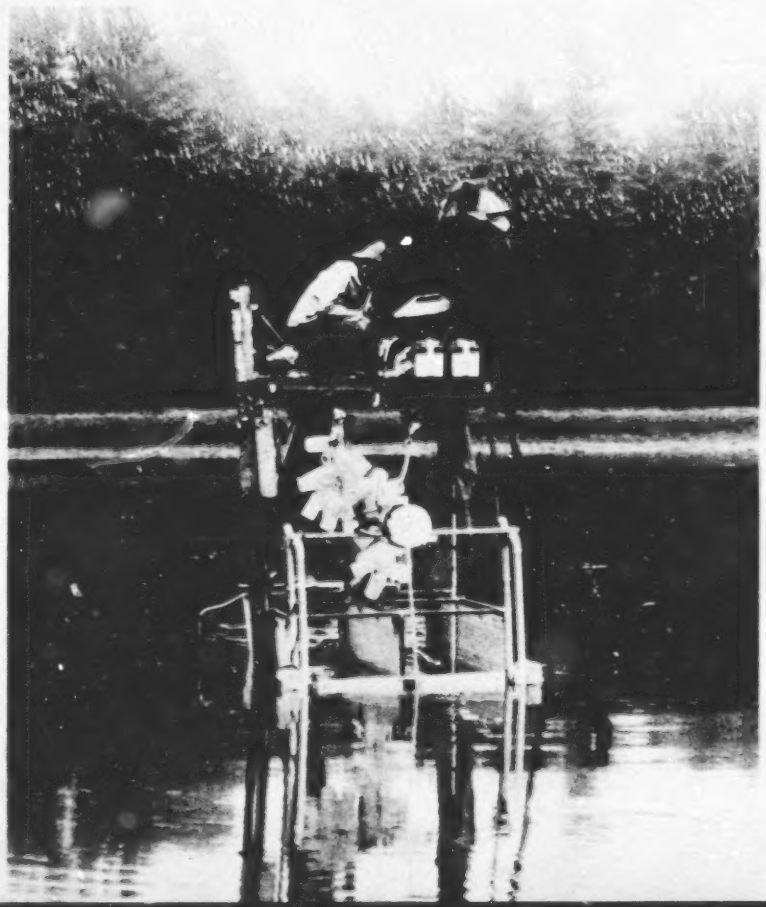
usually in coastal locations, and sometimes aboard a research vessel. Some ocean physicists are pure theorists, working solely in laboratories, using such techniques as computer modeling to turn data and their own special knowledge into hypotheses about how the oceans work, why, and what that means. The scientists who do go to sea bring back data to support, disprove, or suggest new theories. But the scientist who can resist being *on* his subject is rare, and most physical oceanographers are both theorists and field researchers, both posing and setting out to sea to prove their theories.

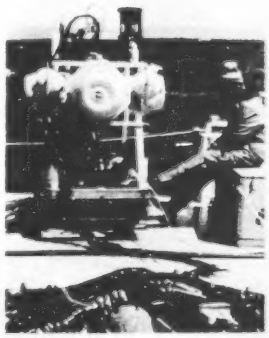
The amount of time spent at sea, "in the field," varies with the nature of the research a scientist is doing. Deep-sea research is very costly, because of the size of the ships necessary and the distances that have to be traveled. Consequently, a number of scientists, including biologists, chemists, geologists, and others with deep-sea experiments to conduct, will usually go on a deep-sea expedition together. Such a trip might last six to nine months.

A study of the behavior on the continental shelf or in near-shore waters might require only a few hours, or it might take a few days, or even weeks on the water. Often, the length of such trips is determined by the kind of monitoring being done, and whether it requires continuous data collection by the scientists or only the deployment of data-gathering equipment that can be left in the water. The latter sort of experiment provides the context for this ocean story.

On the continental shelf off the coast of California, a group of physical oceanographers is studying the wind-driven circulation of the water. Their research will determine how wind energy is translated into water movement, and they hope to solve the mystery of how wind can generate currents far below the ocean's surface. What they are trying to do, of course, is understand the physics involved.

What they find out will help other ocean scientists investigating such things as sediment transport from places like San Francisco Bay and the Columbia River. The continental shelves are also major fishing

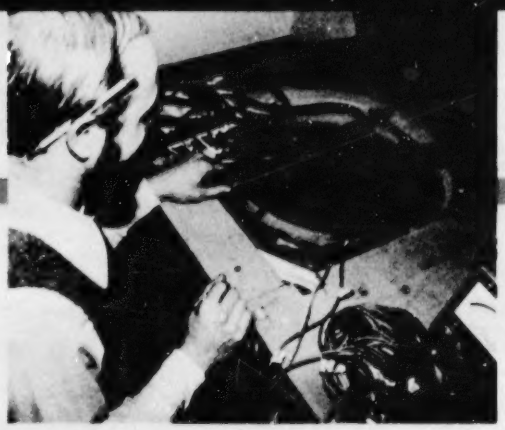




Meteorologist: studies atmospheric conditions and the relationships to wave propagation and tidal heights; conducts research on long-range forecasting, radio waves, and severe weather phenomena such as typhoons and hurricanes.

Computer operator: is responsible for the maintenance of computer hardware and operations on shipboard and on land.

Oceanographic instrumentation technician: adjusts, calibrates, repairs, and determines accuracy of instruments; modifies and/or designs new auxiliary apparatus if necessary.



grounds, and how the waters move has a lot to do with where the fish are. Shelf locations are also prime sites for off-shore drilling; information from this study will help locate the safest sites for those operations.

To discover how deep water is moved by surface winds, these physical oceanographers are measuring the pressure of the water on the bottom of the ocean. Ocean water pressure is like air pressure in the atmosphere, where low-pressure systems circulate counter-clockwise and high-pressure systems move clockwise (in the Northern Hemisphere, anyway). By determining whether the pressure at the bottom is high or low, the scientists can tell which way the water is moving.

Of course you can't do this with one instrument in one place. The measuring is done by a number of instruments placed in a pattern on the ocean bottom. Some simply record, on cassette tapes, electrical impulses from pressure sensors. Other "smart" instruments can do much more, because they contain microprocessors like the ones the engineers use to give their robots intelligence. Smart instruments are capable of taking a number of different readings, including salinity, temperature, density, and velocity, as well as pressure. An array of sensors, suspended above the main instrument from a buoy, takes measurements in the water column, too. Because you can only store so much information on a cassette—and some of these instruments are on the bottom for more than a year—a smart instrument is programmed to stop measuring, say, temperature, if it has remained constant for some time, and to increase measurement of a more interesting variable, like density.

Along with their undersea instruments, the physicists will also deploy surface buoys with meters for wind, sunlight, surface currents, and other phenomenon. When everything is in place, the scientists go home. After awhile—a carefully planned while—they come back and recover the instruments and the data on their tapes. Aboard the research vessel, the scientists have installed a portable laboratory with banks of electronic instruments, including computers, oscilloscopes, counters, amplifiers, and other tools of their trade. Once the instruments from the waters have been winched on board, their cassettes are played through the lab instruments, yielding the information collected and stored there. The tape can then be replaced and the instruments moved to a new location for more "mapping" of ocean currents.

The oceanographers, meanwhile, return to shore to weave together their new information about temperature, salinity, velocity, direction, surface currents, and wind speed. The information will help construct computer models of what the ocean was doing and why, from which the trained physical oceanographer can make new theories and discoveries of how the oceans work as a whole.

The theories will be tested again; the discoveries will be used by other scientists in their studies, as the physical oceanographers make their contributions to the pool of knowledge about the oceans. Using instruments created and built by ocean engineers, and working with information gathered by biologists, geologists, chemists, and others, they help reveal the ocean's magic so we can use it wisely.

Marine technician: (see chapter four)

Oceanographic technician: (see chapter three)

Applied research technician: (see chapter three)

Dock support technician: (see chapter one)

Scientific diver or underwater technician: (see chapter one)

Hydrographic survey technician: (see chapter four)

Technical writer: (see chapter six)

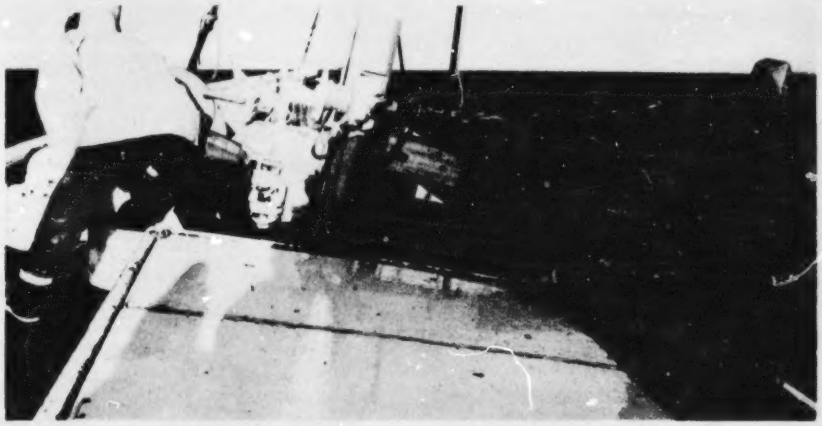
Computer programmer: (see chapter two)

Systems programmer: (see chapter two)

Applied statistician:(see chapter one)

CHAPTER 6
Social Sciences & the Sea

or:
A Life on the ocean wave,
a home on the rolling deep.
—Epes Sargent;
from *A Life on the Ocean Wave*



This is the orange in the apple cart. We have, until now, told the stories of scientific careers in the ocean. But this chapter is different. It is not an ocean story, but a discussion and digression, and brief at that. Given the choice between being brief and going on forever, we decided to be brief. Saves trees.

You may think "going on forever" is an overstatement, and it is, but not by much. To illustrate that point, try playing a little game with a friend: name a profession that could not be associated with the ocean. Don't be *too* literal (Obviously, a beet farmer does not work in the ocean, but there *are* ocean farmers), but don't throw caution to the wind either. For every one you think of, score ten points. For every one you think of that could be an ocean career after all, subtract twenty points. It's not easy, especially when you think of all the recreational activities—from water skiing to cruising on an ocean liner—and the people who work in those areas.

But to narrow the focus a bit, there are some very important political and social issues revolving around the oceans today. From Thermopylae to Trafalgar and Midway Island to the Falkland Islands, people have tried to control the oceans—because that meant controlling the land. But as the oceans themselves have become valuable resources, we need to control the oceans and their uses, and that is a difficult notion.

The concept of "international waters" has been around for a long time: some parts of the ocean don't belong to anyone. After all, nobody lives there, so such waters "belong" to nobody. Today, however, the regulation and wise use of those waters—and the species that live there and the land beneath them—is one of the most complex and important issues we face.

Some of the problems inherent in regulating international waters, like protecting certain species from extinction, are familiar to us. As the oceans are developed for mineral resources, the nature and number of the problems increases in complexity and size.

When we talk about fishing or mining, of course, we are talking about busi-

Marine economist: studies and analyzes economic factors in marine-related production and products distribution, and the use of goods or services, such as production costs and techniques, financing methods, and marketing policies; studies the organizational structure of marine-related businesses, relationships to marketing, and effects of government regulations and requirements.

Marine manager: studies and coordinates uses of the coastal zone, and the distribution, usage, and protection of marine resources; uses data gathered in scientific studies to work toward the best use of living resources; deals with businesses, markets, law, and business and public administrators.

Market research analyst: analyzes market conditions for marine products; analyzes supply and demand and potential sales of products.

ness. And if we are talking about ocean fishing and mining, we are talking pretty big business, which means we are talking about economic effect when we talk about regulation. For instance, if the New England fishing fleet were free to haul as much haddock off the Grand Banks as it could, the price of haddock would go down, more people would buy more fish, the fishermen would buy more boats, catch more fish, and so on . . . until the haddock ran out. Then we'd switch to cusk.

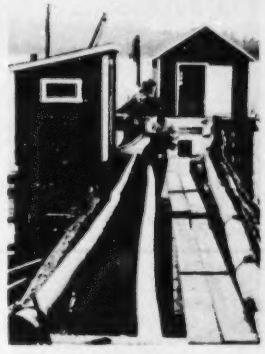
That is grand oversimplification and fishermen are smarter than that, but it illustrates the point: if you regulate the amount of haddock that can be caught, you are, to some extent, regulating the price of haddock as well. And the same is true, in different ways and to differing degrees, of off-shore oil drilling or seabed mining.

Drilling and mining are new concepts in the spectrum of ocean work (mining is barely a reality at all)—like the farming of blue mussels we encountered in chapter one. As we add new enterprises to the list of ocean activities, we add new people, too. Many of those people don't lead lives like most of us, because their work often requires them to be away from home for long periods of time. Some of the ocean researchers we've already met, especially if they are involved in deep-ocean projects, have such "tours of duty."

There are a variety of effects from such work, from being away from home, being out at sea, being in quarters that are somewhat confined, on the average—factors of environment that affect the person and the work. As ocean technology progresses, some living environments will probably be on the ocean floor.

There are many ways of making far-from-home more like home. Good cooking is one—and good cooks are much in demand. Recreation is another; making sure people can get exercise and take their minds off their work. Another way is to make the surroundings comfortable and attractive.

Marine food scientist: studies various aspects of marine foods such as nutritional value, preservation, and preparation techniques, marketing, and new uses and markets for underutilized food resources from the sea.



Marine sociologist: is concerned with the law-of-the-sea, the economics of resource recovery, the social and psychological factors concerning work in and around the water.

Marine biomedical specialist/physician: applies medical knowledge to unique medical problems encountered by people working in the marine environment, such as diving physiology.

Museum and aqdarium administrator: manages the business aspects and oversees the preparation and maintenance of displays and exhibits.

Looking back over the preceding paragraphs, you will find we've talked about jobs for interior decorators, recreation counselors, exercise specialists, cooks, nutritionists, and implied the presence of many other professionals in the new world of ocean work. But before the needs of people living in ocean environments can be detailed, they will have to be studied, and that is the work of sociologists and psychologists. They can study those needs, however, only if the environments exist—as some, like drilling rigs and nuclear submarines, already do. That, clearly, means that the businesses supporting those environments have to be operating, but before that can happen, national and international agreements have to be reached.

At present, the United States and more than 90 other countries are quietly at work, attempting to forge "the law of the sea," a massive treaty upon which succeeding regulations could be based in the areas of fisheries, ocean-floor mining, drilling, and others.

In 1976, the United States, concerned over marked reductions in catches in prime fishing areas, instituted the Fishery Conservation and Management Act (FCMA), which many people call the "200-mile limit." Many of those people mistakenly believe that refers to the expansion of U.S. territorial waters to 200 miles off shore, but the idea behind the act was to allow the U.S. to regulate the kinds of fishing done in those waters—some of the most productive in the world—in order to guarantee a lasting fishery.

To appreciate the complexity of that act of Congress and international reaction, one need only ponder for a moment the fact that Cuba is 90 miles off the tip of Florida. Add to that the fact that fishing vessels from many nations, including Russia, regularly operated well within that limit, and you can see that a "law of the sea" is an important but delicate thing.

Negotiations around the fisheries act and the law of the sea continue, marine lawyers and political scientists attempting to cope with and sort out a tangle of international and national laws, wishes, dreams, and beliefs in order to create a workable code for ocean use.

In the meantime, marine economists are at work determining the effects of different kinds of regulations on the fishing, oil, mining, shipping, recreation, and other industries. They must formulate theories based on myriad variables, including seasons, vessel sizes and types, fish species, locations, past and projected market values, supply, and demand. After computation and analysis, they propose quotas and other economic restraints—often using data from ocean scientists. Their proposals, like the regulations of the lawyers, must meet the approval of a diverse audience—from corporate executives and grocery shoppers to fishing boat operators and restaurateurs.

Whether they work on land or at sea, in the culinary arts or economics, recreation or mediation, there are jobs in ocean work for all kinds of people. Just as the different fields of ocean sciences are interwoven, sharing information and ideas, people in the social sciences, the humanities, health services, recreation, the arts—even the performing arts—all share in the opportunities that the oceans present us.

Marine veterinarian: treats illnesses and injuries as well as studies diseases of the marine mammals, fish, and other vertebrates.

Maritime lawyer: interprets and implements national and international marine law and laws governing coastal zone management, shipping on inland waters and the high seas, etc.

Education personnel: prepare and disseminate a broad range of marine education materials useful to students, teachers, and the general public; provide instruction on environmental and marine-related issues, and the role of citizens in solving these problems.

Technical writer: produces manuals and technical publications dealing with all aspects of marine work.

Computer programmer: (see chapter two)

Computer operator: (see chapter five)

Systems programmer: (see chapter two)

Applied statistician: (see chapter one)

APPENDIX

The following is an extensive listing of colleges, universities, schools, and other institutions and agencies that offer programs in ocean and marine studies. Some are career-training programs, some offer certificates, and most are degree-granting programs.

A complete listing, including kinds of degrees, more specific departmental information, and names, is available from the Marine Technology Society, for a small fee.

Adelphi University
Marine Program Coordinator
Department of Biology
Adelphi University
Garden City, Long Island, New York 11530

Alabama State University
Division of Biological Sciences
Alabama State University
Montgomery, Alabama 36101

The University of Alabama
Marine Science or
Department of Biology
The University of Alabama
University, Alabama 35486

University of Alaska
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

The American University
Environmental and Marine Science
Department of Biology
The American University
Washington, DC 20016

Anne Arundel Community College
Marine Technologies
Anne Arundel Community College
101 College Parkway
Arnold, Maryland 21012

University of Arizona
Marine Sciences Program
The University of Arizona
Tucson, Arizona 85721

Bellingham Vocational-Technical Institute
Admissions
Bellingham Vocational-Technical Institute
Bellingham, Washington 98225

Boston University
Director
Boston University Marine Program
Marine Biological Laboratory
Woods Hole, Massachusetts 02543

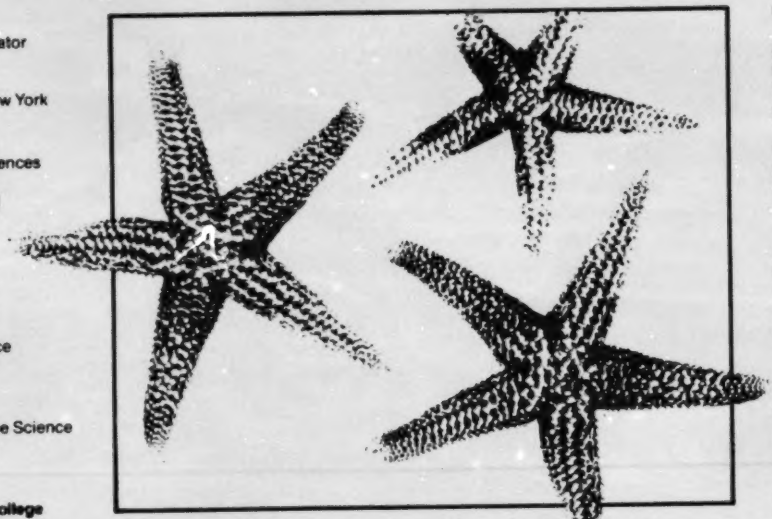
Bowling Green State University
Department of Biological Sciences
Bowling Green State University
Bowling Green, Ohio 43403

Brazosport College
Oceanic and Marine Technology
Brazosport College
Lake Jackson, Texas 77566

Brown University
Department of Geological Sciences
Brown University
Providence, Rhode Island 02912

California Institute of Technology
Geological and Planetary Sciences
California Institute of Technology
Pasadena, California 91125

California Maritime Academy
Director of Admissions
California Maritime Academy
Vallejo, California 94590



California Polytechnic State University
Biological Sciences Department
California Polytechnical State University
San Luis Obispo, California 93407

Humboldt State University
Department of Biology,
Environmental Resources Engineering,
Fisheries, or Oceanography
Humboldt State University
Arcata, California 95531

California State College, Stanislaus
Biology Department
California State College, Stanislaus
Turlock, California 95380

California State Polytechnic University, Pomona
Department of Ocean Engineering
California State Polytechnic University
Pomona, California 91768

California State University, Dominguez Hills
Marine Sciences
California State University,
Dominguez Hills
Carson, California 90747

California State University, Fresno
Biology Department
California State University
Fresno, California 93740

California State University, Hayward
Department of Biological Sciences,
Department of Geological Sciences
California State University
Hayward, California 94542

California State University, Los Angeles
Department of Biology
California State University
5151 State University Drive
Los Angeles, California 90032

California State University, Sacramento
Department of Biological Sciences,
Department of Geology
California State University
Sacramento, California 95819

San Diego State University
Center for Marine Studies,
Departments of Botany, Biology, Chemistry, Civil Engineering, Economics, Geography, Geological Sciences, Microbiology, or Political Science
San Diego State University
San Diego, California 92181

San Francisco State University
Department of Biology
San Francisco State University
San Francisco, California 94132

San Jose State University
Department of Biological Sciences
San Jose State University
San Jose, California 95192

Sonoma State University
Marine Biology
Sonoma State University
Rohnert Park, California 94928

University of California, Berkeley
Department of Botany, Civil Engineering, Geology and Geophysics, Naval Architecture, Paleontology, or Zoology
University of California
Berkeley, California 94720

University of California, Davis
Director, Aquaculture Program;
Department of Wildlife and Fisheries Biology; or Division of Environmental Studies
University of California
Davis, California 95616

University of California, Irvine
Department of Ecology and Evolutionary Biology
University of California, Irvine
Irvine, California 92171

University of California, Los Angeles
Planning Office
University of California, Los Angeles
Los Angeles, California 90024

University of California, Santa Barbara
Department of Biological Science
or
Director
Marine Science Institute
University of California
Santa Barbara, California 93106

University of Southern California
Institute for Marine and Coastal Studies
University of Southern California
Los Angeles, California 90007

Cape Fear Technical Institute
Director
Marine Division
Cape Fear Technical Institute
Wilmington, North Carolina 28401

The Catholic University of America
Institute of Ocean Science and Engineering
Catholic University of America
Washington, DC 20017

Charles County Community College
Department of Marine Sciences
Charles County Community College
La Plata, Maryland 20646

University of Chicago
Department of Geophysical Sciences
The University of Chicago
5734 South Ellis Avenue
Chicago, Illinois 60637

Claremont Men's College
Joint Science Department
Claremont Men's College
Claremont, California

Clark University
Department of Biology
Clark University
Worcester, Massachusetts 01610

Clatsop Community College
Director of Admissions
Clatsop Community College
Astoria, Oregon 97103

Clemson University
Dean of Admissions
Clemson University
Clemson, South Carolina 29631

College Center of the Finger Lakes
College Center of the Finger Lakes
22 West Third St.
Corning, New York 14830

University of Connecticut
Marine Sciences Institute
The University of Connecticut
Avery Point, Groton,
Connecticut 06340

Cornell University
Water Resources or Marine Science
Cornell University
Ithaca, New York 14853

University of Delaware
College of Marine Studies or
Ocean Engineering Program
Department of Civil Engineering
University of Delaware
Newark, Delaware 19711

Dominican College of San Rafael
Department of Biology
Dominican College of San Rafael
San Rafael, California 94901

Dowling College
Director
Marine Sciences Program
Dowling College
Oakdale, New York 11769

Drake University
Department of Geology
Drake University
Des Moines, Iowa 50311

Duke University
Director
Duke University Marine Laboratory
Beaufort, North Carolina 28516

East Carolina University
Institute for Coastal and Marine Resources
East Carolina University
Greenville, North Carolina 27834

The Evergreen State College
The Evergreen State College
Olympia, Washington 98505

Florida Atlantic University
Department of Biological Sciences
Florida Atlantic University
Boca Raton, Florida 33431

Florida Institute of Technology
Director of Admissions
Florida Institute of Technology
School of Applied Technology
Jensen Beach, Florida 33457
or
Department of Oceanography and
Ocean Engineering
Florida Institute of Technology
Melbourne, Florida 32901

Florida International University
Marine Science Program Coordinator
Department of Biological Sciences
Florida International University
Miami, Florida 33199

Florida State University
Admissions Committee
Department of Oceanography
Florida State University
Tallahassee, Florida 32306

University of Florida
Center for Aquatic Studies
University of Florida
Gainesville, Florida 32601

University of South Florida
Department of Marine Science
University of South Florida
St. Petersburg, Florida 33701

University of West Florida
College of Arts and Sciences
The University of West Florida
Pensacola, Florida 32504

Fullerton College
Division of Life Sciences
Fullerton College
321 East Chapman Avenue
Fullerton, California 92634

Georgia Institute of Technology
School of Biology
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia 30332

University of Georgia
(Department of Interest)
University of Georgia
Athens, Georgia 30602

Gulf Coast Community College
Technical Division
Gulf Coast Community College
Panama City, Florida 32401

University of Hawaii
Marine Programs
Honolulu, Hawaii 96822

Highline Community College
Highline Community College
Midway, Washington 98031

University of Houston
Department of Biology
University of Houston
Houston, Texas 77004

Immaculate Heart College
Immaculate Heart College
2021 N. Western Avenue
Los Angeles, California 90027

Eastern Kentucky University
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

Lamar University
College of Sciences
Lamar University
Beaumont, Texas 77710

Lehigh University
Center for Marine and Environmental Studies
Lehigh University
Bethlehem, Pennsylvania 18015

Long Island University
Southampton College
Marine Sciences Program
Southampton College
Southampton, New York 11968

Los Angeles Pierce College
Marine Biology
Los Angeles Pierce College
6201 Winnetka Avenue
Woodland Hills, California 91364

Louisiana State University
Department of Marine Sciences
Louisiana State University
Baton Rouge, Louisiana 70803

University of Southwestern Louisiana
Department of Biology
University of Southwestern Louisiana
Lafayette, Louisiana 70504

Maine Maritime Academy
Director of Admisssions
Maine Maritime Academy
Castine, Maine 04421

Southern Maine Vocational Technical Institute
Director of Admissions
Southern Maine Vocational
Technical Institute
South Portland, Maine 04106

University of Maine
Center for Marine Studies
University of Maine at Orono
Orono, Maine 04469

University of Maryland
(Department of Interest)
University of Maryland
College Park, Maryland 20742

Massachusetts Institute of Technology
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Massachusetts Maritime Academy
Academic Dean
Massachusetts Maritime Academy
Buzzards Bay, Massachusetts 02532

Southeastern Massachusetts University
Department of Biology
Southeastern Massachusetts University
North Dartmouth, Massachusetts 02747

University of Massachusetts
Marine Studies
University of Massachusetts
Amherst, Massachusetts 01003

Miami Dade Community College
Marine Science Technology Department
Miami Dade Community College
1090 N.W. North River Drive
Miami, Florida 33136

University of Miami
School for Marine and Atmospheric Sciences
University of Miami
Miami, Florida 33149

University of Michigan
Department of Naval Architecture and Marine Engineering
University of Michigan
Ann Arbor, Michigan 48109

Michigan State University
Department of Geology
Michigan State University
East Lansing, Michigan 48823

University of Minnesota
Director of Studies in Fisheries
University of Minnesota
St. Paul, Minnesota 55108

Mississippi State University
Drawer ME
Mississippi State, Mississippi 39762

University of Mississippi
Associate Director of Research
University of Mississippi
University, Mississippi 38677

Southwest Missouri State University
Department of Life Sciences
Southwest Missouri State University
Springfield, Missouri 65802

University of New England
Center for Life Sciences
University of New England
Saint Francis College
Biddeford, Maine 04005

University of New Hampshire
University of New Hampshire
Marine Program
University of New Hampshire
Durham, New Hampshire 03824

New Jersey Marine Sciences Consortium
Educational Programs
New Jersey Marine Sciences Consortium
Princeton Forrestal Center
Princeton, New Jersey 08540

City College of New York
Institute of Marine and Atmospheric Sciences
City College of New York
Convent Avenue at 138 Street
New York, New York 10031

The City University of New York
Queens College
Department of Earth and Environmental Sciences
Queens College
Flushing, New York 11367

State University of New York at Stony Brook
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794

State University of New York
Agricultural and Technical College
Department of Biological Sciences
State University, Agricultural and Technical College
Farmingdale, New York 11735

State University of New York
College of Arts and Science
Department of Earth Sciences
State University of New York
Oswego, New York 13126

State University of New York
The Maritime College
Department of Marine Transportation,
Department of Engineering,
or Director, Continuing Education
SUNY Maritime College
Fort Schuyler,
Bronx, New York 10465

Nicholls State University
Nicholls State University Marine Laboratory
Department of Biological Sciences
Thibodaux, Louisiana 70301

North Carolina State University
Marine Science and Engineering
North Carolina State University
Raleigh, North Carolina 27650

University of North Carolina at Wilmington
Director
Program in Marine Sciences
University of North Carolina at Wilmington
Wilmington, North Carolina 28403

University of North Dakota
Department of Biology
University of North Dakota
Grand Forks, North Dakota

Northeastern University
Marine Institute
Northeastern University
Boston, Massachusetts 02115

College of Notre Dame
Marine Resources Center
College of Notre Dame
Belmont, California 94002

Occidental College
Biology Department
Occidental College
1600 Campus Road
Los Angeles, California 90041

The Ohio State University
Center for Lake Erie Area Research
The Ohio State University
Columbus, Ohio 43210

Orange Coast College
Department of Marine Sciences
Orange Coast College
Costa Mesa, California 92626

Oregon State University
School of Oceanography,
School of Engineering,
Oregon State University
Corvallis, Oregon 97331
or
Director,
OSU Marine Science Center
Newport, Oregon 97365

University of Oregon
Oregon Institute of Marine Biology
Charleston, Oregon 97420

Pacific Union College
Department of Biology
Pacific Union College
Angwin, California 94508

University of the Pacific
Director
University of the Pacific
Pacific Marine Station
Dillon Beach, California 94929

Peninsula College
Director
Vocational Education
Peninsula College
Port Angeles, Washington 98362

The Pennsylvania State University
Marine Science Committee
The Pennsylvania State University
University Park, Pennsylvania 16820

Pitzer College
Joint Science Department
Claremont Men's College
Claremont, California 91711

Pomona College
Biology Department
Pomona College
Claremont, California 91711

Princeton University
Department of Geological
and Geophysical Sciences
Princeton University
Princeton, New Jersey 08544

University of Rhode Island
Department of Engineering,
Department of Fisheries and Marine
Technology, Department of
Geography and Marine Affairs,
Department of Mechanical
Engineering, Department of
Resource Economics,
or
Director
Marine Affairs Program
University of Rhode Island
Kingston, Rhode Island 02881

Rice University
Department of Biology
Department of Geology
Rice University
Houston, Texas 77001

Roger Williams College
Natural Science Division
Roger Williams College
Bristol, Rhode Island 02809

Rutgers—The State University of New Jersey
Marine Sciences Center
Rutgers—The State University
of New Jersey
New Brunswick, New Jersey 08903

Saddleback College
Coordinator
Marine Science Programs
Saddleback College
Mission Viejo, California 92692

St. John's University
Department of Biology
St. John's University
Grand Central and Utopia Parkways
Jamaica, New York 11439

St. Mary's College of California
Biology Department
Saint Mary's College
Moraga, California 94575

San Diego Community Colleges
Mesa College, Evening College
Coordinator
Vocational Education
San Diego Community College
District
3375 Camino del Rio South
San Diego, California 92108

University of San Diego
Department of Biology
University of San Diego
Alcala Park
San Diego, California 92110

University of San Francisco
Biology Department
University of San Francisco
San Francisco, California 94117

Santa Barbara City College
(Department of Interest)
Santa Barbara City College
Santa Barbara, California 93109

Scripps College
Joint Science Department
Claremont Men's College
Claremont, California 91711

Seattle Central Community College
Seattle Central Community College
4455 Shilshole Avenue, N.W.
Seattle, Washington 98107

Seattle Pacific University
Marine Biology Program
Seattle Pacific University
Seattle, Washington 98119

Sheldon Jackson College
Academic Dean
Sheldon Jackson College
Sitka, Alaska 99835

Shoreline Community College
Science Division
Shoreline Community College
16101 Greenwood Avenue North
Seattle, Washington 98133

Skyline College
Director of Science and Math
Programs
Skyline College
San Bruno, California 94066

University of South Carolina
Director
Marine Sciences Program
University of South Carolina
Columbia, South Carolina 29208

Stephens College
Director
Marine Sciences
Department of Natural Science
Stephens College
Columbia, Missouri 65201

Stevens Institute of Technology
Department of Ocean Engineering
Stevens Institute of Technology
Castle Point Station
Hoboken, New Jersey 07030

Suffolk County Community College
Suffolk County Community College
Speonk Riverhead Road
Riverhead, New York 11901

Suffolk University
Admissions
Suffolk University
Boston, Massachusetts 02114

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United States Naval Academy
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